INFLUENCES OF SITE LOCATION UPON ENERGY CONTENT OF SEEDS OF SOME COMMON PLANTS OF NORTHEASTERN KANSAS

by

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INTRODUCTION AND REVIEW OF LITERATURE

The study of bioenergetics is relatively new to the field of ecology. Since Lindeman (1942) postulated his trophic or energy level concept, ecologists have become more aware of energy relationships within ecosystems. Such classic studies as those of Juday (1940), concerned with the energy budget of an inland lake; Odum and Odum (1955) concerned with the trophic structures and productivity of a coral reef community; and Odum (1957) with investigations into the trophic structure of Silver Springs, Florida, indicated the need for energetics research. Teal (1957) made investigations into energy relationships in a cold spring, and Golley (1960) reported on energy dynamics of an old field community. These studies indicate the recent interest in energetics studies. Slobodkin (1962) and Phillipson (1966) discussed the relevance of energy studies to ecology and have presented a review of material concerning the study of energetics in animal communities. Long (1934) introduced calorimetric procedures to ecology, and emphasized the importance of such tools in ecological research.

A study of avian bioenergetics has been in progress at Kansas State University, Manhattan, since November 1961. Basic to comprehensive studies of the energy dynamics of an organism, it is necessary to be aware of variations in energy content of foods available to, and consumed by that organism. When bioenergetics studies are conducted on unconfined granivores,

differences in energy content of consumed seeds may be of major importance. Davis (1951:12) suggested that plants growing on infertile soils supplied inadequate energy requirements for domestic and wild animal growth.

Little information is available concerning the influences of site upon energy values of seeds. However, workers in the field of agriculture have been concerned with problems of food production, energy requirements, efficiency of food utilization and general animal nutrition for many years. Sufficient information is available concerning the effects of the environment upon plant growth in general. The seed or fruit is an integral part of the plant, thus one may assume that influences upon the plant as a whole may affect the quality as well as quantity of seeds produced by that plant. Kraus (1925:514) has substantiated this assumption with experimental data suggesting all growth after initiation of fruiting is primarily devoted to seed or fruit production. Moulton (1918) discussed energy requirements for growth and provided a general review of early energetics concepts. Fraps (1944) reported the production energies of feeds as related to their age and also reported energy values of feeds for domestic fowl; similarly, Robel and Harper (1965) gave gross energy values of two species of wild seeds utilized by unconfined bobwhites (Colinus virginianus). Armsby and Fries (1916 and 1917) presented net energy values of hominy (Zea mays) and maize (Sorghum vulgare) meal for cattle and also determined net energy values of feeds consumed

by other ruminants.

Many studies have been conducted to ascertain the chemical compositions of forage plants utilized by animals. Fudge and Fraps (1944) reported the relationship of different soils to the chemical composition of forage grasses from the Gulf Coast Prairie. The nutritive value of pastures was discussed in great detail by Woodman et al. (1926, 1927, and 1929). Auchter (1939) stated the composition of plants grown on different soils in the same climatic regions vary both in organic and inorganic constituents. Edwards and Goff (1935), however, found no correlation between chemical composition of five species of grasses and different soils of four growth sites in Hawaii. Stoddart (1941) studied the influences of soil, site and date of collection on the chemical composition of snowberry (*Symphoricarpos rotundifolius*), and stated that site had a highly significant influence upon protein content and that soil type significantly influenced total ash and protein content in the plants.

Gradually, bioenergetics research involved with primary consumers became centered around the requirements and factors affecting production of primary producers. Soil structure, texture and depth were found to influence growth, production, nutrition and composition of plants (Stephenson and Schuster 1937). Albrecht (1941) discussed conditions favorable for soil organic matter and ion availability for plants. Stitt (1958) reported yields of seven species of grasses were highly

correlated with precipitation during the April-May period and the nitrogen content of the soil. Weather conditions, thickness of A_1 horizon, soil density and slope aspect affected seed yields of corn (Zea mays) (Odell 1950). Van der Paauw (1962) has shown that alternating periods of low or high rainfall affected soil fertility, plant yields and responses of plants to fertilization. Experimental data from six bluegrass (Poa pratensis) pastures in Pennsylvania showed a correlation between soil properties and pasture productivity (Wynd and Steinbaur 1948). However, soil texture was found to have no affect upon the growth rate of red pine (Pinus resinosa) in lower Michigan (Van Eck and Whiteside 1963). App and Wolf (1945:313) have shown the influence of soil organic matter and pH on the yields of some vegetable crops and stated that a soil organic matter content of 1.5 percent and soil pH between 6.0 and 6.5 was most satisfactory for cultivated legumes. Gray et al. (1957:357) mentioned differences "as yet undetermined" associated with two different growth sites influenced the composition of turnip (Brassica sp.) greens enough to significantly affect their nutritive value as animal foods. The importance of water as an agent of food and nutrient transfer to the plant through the root hairs was discussed by Auchter (1939). Slope drainage and soil particle size had major effects upon the growth and production of black locust (Robinia pseudo-acacia) and black walnut (Juglans niger), however, soil pH had no effect upon these species (Auten 1945). Beeson (1955) reported the nutrient

element content of broomsedge (Andropogon virginicus) and switch cane (Arundinaria tecta) in relation to location and land forms in South Carolina Coastal Plains. Seed yields and evapo-transpiration rates of sudangrass (Sorghum vulgare var. sudanense), starr millet (Panicum sp.) and sart sorghum (Sorghum vulgare var. sart) increased as available soil moisture levels increased (Bennet et al. 1964). Cook and Harris (1950:43) reported the effects of site presented marked differences in the stem-leaf ratio and protein and ash content of seeded wheat grasses (Agropyron spp.) in Utah. Crockett (1964) found soil type and geological formation to influence the distribution of plants in the Wichita Mountains Wildlife Refuge of Oklahoma. Similarly, Gates et al. (1956) found that soils influenced plant distribution on salt-deserts in Utah. However, Dunn and Lyford (1946) reported soil texture did not markedly affect the growth of barley (Hordeum vulgare), sunflowers (Helianthus spp.) or potatoes (Solanum tuberosum). Kik (1943) stated that the nutritive value of herbage of forage species may be affected by soil fertility, soil moisture, soil type, temperature and botanical composition. McVickar (1949) found no significant correlation between nutrient content of white oak (Quercus alba) leaves and corresponding values for the A horizons of the soils on which the trees were growing. Wright (1962) reported that soil water-deprivation treatments did not markedly influence yield or percent protein in blue panicgrass (Panicum antidotale). However, Cornelius (1950) stated that seed production of wild grasses in Kansas was dependent upon favorable

moisture relations, moderate air temperature and fairly high humidity. Long (1934:336) stated that in plants, soil series yielded the most "consistent and striking modification in response to varying water content." Ward (1959) suggested that a balanced nutrient supply, whether at a low or high level, generally resulted in forage of approximately the same nutrient composition, but caused variation in seed yields. Crist and Weaver (1924) found chemical composition of the soil, especially the concentrations of nitrogen and phosphorus, significantly influenced the yield of barley seeds. West and Meng (1966:610) found no significant differences in energy content of plant parts of willows (*Salix spp.*) of the same species at different locations in Alaska. However, in California, Long (1934) observed differences in energy values of plants in response to light intensity, soil type, length of day and amount of soil nutrients. West (1967) presented detailed information on the bioenergetics of the tree sparrow (*Spizella arborea*) in Illinois and discussed energies of foods consumed as well as efficiencies of food utilization. Similarly, Zimmerman (1965) discussed the bioenergetics of the dickcissel (*Spiza americana*) in both its tropical wintering and temperate breeding ranges. Ellison (1966) reported energy contents of foods consumed by Alaskan spruce grouse (*Canachites canadensis*) in Alaska and observed no significant difference in energy contents of two species of spruce (*Picea glauca* and *P. mariana*) needles. Kendeigh and West (1965:544) presented

caloric values of winter foods eaten by birds and stated that significant variation occurs in the caloric content of seeds of different plant families and of species within the same family, however, no data were presented for intraspecific variability. After examining over 600 records of plants, Golley (1961:583) reported that significant differences in energy (caloric) content existed between plants collected in different months and between plants collected in different communities. Bliss (1962) reported caloric and lipid content of alpine tundra plants. Wide ranges in fats present in plant tissues are presented by Morrison (1949:Table 1). McNair (1945) provided a discussion of lipid content of plants and lipid variation with successive stages of growth and maturity. McNair (1945:52) also pointed out, as did Bliss (1962:856), that with increasing altitude and latitude and decreasing temperature, there is a marked increase in caloric value of plant material.

Since energetics is so essential to the understanding of an ecosystem, and because the main producers of energy for granivores are seeds, fluctuations in their energy content are of major importance to ecologists. In the fall of 1966, a study was initiated to determine the effects of growth site upon the energy content of seeds consumed by bobwhites in the Flint Hills region of northeastern Kansas.

MATERIALS AND METHODS

The Study Area

The Kansas Flint Hills region is a 20-mile wide topographic unit that extends entirely across Kansas from Marshall county in the North to Cowley county in the South. This area, lying within the Nemaha uplift, comprises nearly 6,250 square miles and has an average elevation of approximately 1500 feet and a relief of about 350 feet. The streams in the Flint Hills have deep, precipitous channels lined with outcrops of flint-bearing Permian strata (Shoewe 1949). This study was conducted in that portion of the Flint Hills within a 25-mile radius of Manhattan, Kansas.

Five great soil groups are present within the study area; chernozems, brunizems, planosols, lithosols and alluvial soils (Bidwell 1960).

The growing season in the Flint Hills region of Kansas is approximately 180 days, with mean daily temperatures between 24 and 29°C. and a mean relative humidity of approximately 60 percent. The evaporation rate averages between 20 and 30 cubic centimeters of water per week. Rainfall averages 86 centimeters per year, with 80 percent of this amount falling between 1 April and 30 September. A mean of 51 centimeters of snow falls during the winter months. Wind movement is fairly constant throughout the year and often excessive. Wind is an important factor in promoting water loss from soil and plants

(Weaver and Fitzpatrick 1934).

Little bluestem (Andropogon scoparius),[1] big bluestem (A. gerardi), sideoats grama (Bouteloua curtipendula), indiangrass (Sorghastrum nutans) and switchgrass (Panicum virgatum) are the dominant species of grass in this prairie region of Kansas (Herbel and Anderson 1959). Along streams and lowlands, trees and shrubs are dominant species (Weaver and Fitzpatrick 1934).

For the Flint Hills region of northeastern Kansas, Anderson and Fly (1955) described four distinct range growth sites, each with significantly different topography, soils, and quantity and quality of plant material. Each of the four range sites existed in the study area, namely; Lowland, Ordinary Upland, Limestone Breaks and Clay Upland (Plate I).

Lowland sites received more than the normal amount of water, and had postclimax vegetation. The Ordinary Upland range site had adequate moisture to support climax vegetation on the zonal soils. Ordinary Upland range sites included lands with medium or loamy textured soils with sufficient depth for plant growth. Except for being situated on steeper slopes, Limestone Breaks sites are similar to the Ordinary Upland sites. Moisture runoff occurs readily in the Limestone Breaks sites, and the soils are less developed. Plants are similar to those on Ordinary Upland sites and may be considered

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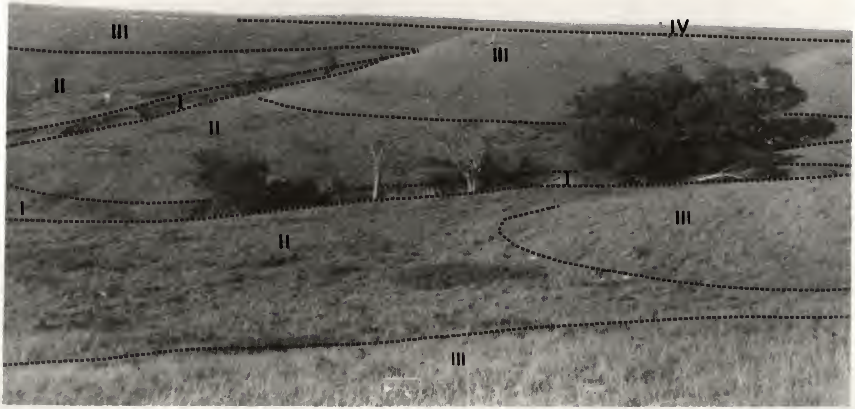
[1]Common and scientific names follow Anderson (1961) and Fernald (1950).

EXPLANATION OF PLATE I

Fig. 1. Range growth sites described by Anderson and Fly (1955). Numerals I, II, III, IV delineate Lowland, Ordinary Upland, Limestone Breaks and Clay Upland sites, respectively.

PLATE I



climax. Clay Upland sites are lands with soils of low permeability. Plant-soil moisture relations are poor on Clay Upland sites, hence a preclimax vegetation exists on these sites. Range site classification and description of major soil units are listed in Table 1.

Seed Collections

Collection of *Rhus glabra* and *Bromus japonicus* seeds was initiated on 26 August 1966. *Ambrosia trifida* and *Cornus drummondi* seeds were first collected on 8 September 1966, while seeds of *Setaria lutescens* were collected first on 25 September 1966. *Helianthus annuus* seeds were first collected on 7 October 1966 and *Solanum rostratum* seeds on 30 October 1966. Collection of *Rhus aromatica* and *Symphoricarpos orbiculatus* seeds was initiated on 13 November 1966. The majority of all samples were collected from 1 September to 30 November 1966. Duplicate collections of some seeds were made at later dates. The last collection made was a replacement sample of *Solanum rostratum* collected on 7 March 1967.

Seeds were collected from one, two, three or all four of the major range growth sites at 21 different locations in Geary, Riley and Pottawatomie counties, Kansas. Collection areas were given numerical values corresponding to the order which they were selected. Legal descriptions of these areas are provided in the Appendix (Table 4). Collection areas were selected on the basis of (1) the presence of well defined range

Table 1. Site classification and major soil unit descriptions.[a]

Soil Survey Mapping Symbol[b]	Growth Site	Soil Unit Description
$\frac{\text{XUX}}{\text{Du-8v}}$	Lowland	Mixed alluvial, colluvial and limestone shale soils on broken irregular slopes along narrow upland drainages with severe gullying and bank cutting.
$\frac{\text{2F3U}}{\text{6I}}$	Ordinary Upland	Gently sloping, deep, silty clay loam colluvial soils with little or no erosion.
$\frac{\text{2F3U}}{\text{10-I}}$		Similar to first soil unit but on steeper slopes and with more chert fragments in subsoil.
$\frac{\text{3gF4C}}{\text{20-I}}$		Strongly sloping, moderately deep, cherty silty clay loam soils with little or no erosion.
$\frac{\text{3gF4CL}}{\text{20-I}}$		Similar to above soils but with limestone fragments in soil and on surface.
$\frac{\text{3Fr4C}}{\text{5 or 8-1}}$		Gently sloping, moderately deep, cherty silty clay loam soils with little or no erosion.
$\frac{\text{4rF4C}}{\text{35-I}}$	Limestone Breaks	Steep, shallow, very cherty silty clay loam soils with little or no erosion.
$\frac{\text{4rF4C}}{\text{45-I}}$		Similar to above but very steep.
$\frac{\text{4vF4CL}}{\text{35-I}}$		Similar to $\frac{\text{4rF4C}}{\text{35-I}}$ but with limestone ledges and numerous limestone rocks exposed.
$\frac{\text{4vF4CL}}{\text{45-I}}$		Similar to above but very steep.

Table 1 (concl.).

Soil Survey Mapping Symbol[b]	Growth Site	Soil Unit Description
2F21E / 6-1	Clay Upland	Gently sloping, moderately deep silty clay loam soils with light clay subsoils over shale, with erosion.
3rF3(1)C / 5-1		Gently sloping, very cherty clay loam soils with light clay subsoils and slight to moderate erosion.

[a]From Anderson and Fly (1955).

[b]National standard symbols for coding soil properties: United States Dept. Ag. Soil Conser. Serv. Guide for Soil Conservation Surveys (1951).

growth sites, (2) the presence of desired plants yielding sufficient quantities of mature seeds for collection, and (3) the assurance that areas were natural and not artificially fertilized. Collections were made from as many plants as possible and as near the center of range sites as possible. Samples of the same species were collected from each of the four range sites in five different areas resulting in 20 seed samples collected for each species.

Seed collection was initiated when dispersal and/or utilization by animals of seeds of a particular species had begun. Seeds of *Rhus glabra* and *R. aromatica*, *Cornus drummondi* and *Symphoricarpos orbiculatus* were picked individually from different plants. *Helianthus annuus* and *Ambrosia trifida* seeds were collected by hand-crushing seed heads. *Bromus japonicus* and *Setaria lutescens* seeds were stripped from the plants by hand. Whole plants of *Solanum rostratum* were clipped and placed on a tarpoline. These plants and their seed bearing capsules were crushed and discarded and the seeds collected from the tarpoline by hand. On certain occasions weather conditions dictated the removal of whole plants to the laboratory where seeds were removed from the plants. Sufficient amounts of seed material were collected to yield at least 5-grams of oven dried seeds. Samples were deposited in polyethylene bags and labeled with date of collection, range growth site from which collected, species and location of collection. Detailed descriptions, including compass bearings were made of exact

locations of each collection.

Seed Processing and Caloric Determination

All seed material was brought directly from the field and stored at -22°C. until analyzed. Respiration at -22°C. is extremely slow and is not thought to cause significant changes in either weight or energy content of seeds (Bailey and Gurjar 1918; Anderson and Alcock 1954). To substantiate this fact, a sample of _Rhus glabra_ collected from area 8 at all growth sites on 19 September 1966, was stored in a freezer for the duration of the study and portions of this sample were analyzed at monthly intervals.

Seeds were separated from plant fragments with the aid of a set of Tyler nested sieves (0.42-4.70 millimeter openings). Damaged or abnormal seeds were sorted and separated from normal ones. Normal _Helianthus annuus_ seeds usually sunk when immersed in a pan of water, whereas, those damaged or hollowed by insect larvae would float. All other seeds were visually inspected to detect insect damage or other abnormalities. Seeds of _Helianthus annuus_, _Ambrosia trifida_, _Rhus glabra_, _R. aromatica_, _Setaria lutescens_ and _Symphoricarpos orbiculatus_ were analyzed with the seed coat present. Glumes, lemmae and paleae were removed from _Bromus japonicus_ seeds by abrading the seed material through a Tyler 0.83 millimeter sieve. A fan was used to blow the chaff from the seeds, which were collected in a smaller 0.59 millimeter sieve. _Cornus drummondi_

fruits were dehydrated in a drying oven at 60°C. for several days, after which the pulpy material surrounding the pit and seeds within, was abraded similarly to the method described for Bromus japonicus. This abrasion resulted in the formation of a "slush" which was water soluble and was washed from the remaining pits. Symphoricarpos orbiculatus produced fruits which varied in size (0.5-7.0 millimeters) but only those larger than 4.70 millimeters in diameter were retained and analyzed.

All seeds were spread evenly in labeled petri dishes and dried at 60°C. for at least 48 hours. Dried seeds were ground in a Wiley Micro model mill, employing 0.83-, 0.51-, and 0.41-millimeter (opening) screens, to assure as much homogeneity of particle size as possible. After milling, seed material was returned to the oven to complete drying before analyzation for energy content. Ground seed material was kept in the drying oven at all times except when weighing samples, pelleting samples, or making calorimetric determinations. Experiments were conducted to determine the effects of absorbed water on energy values of subsamples removed from the drying oven and not stored in a dessicator. Samples were exposed to conditions of known relative humidity and weighed at 5-minute intervals to determine uptake of atmospheric water.

Prior to testing for energy content, each sample of seed material was pelleted in a Parr 2811 press. Optimum pressure to obtain a firm seed pellet varied between species. Seed

material containing large amounts of oil (Rhus glabra and R. aromatica, Cornus drummondi and Solanum rostratum) formed firm pellets under approximately 260 kg/cm^2 of pressure. In contrast, extremely dry seed material (Bromus japonicus and Symphoricarpos orbiculatus) formed firm pellets only after being compressed at approximately 1300 kg/cm^2 pressure for several minutes. Pelleted seed materials were weighed to 0.0001-gram on a Mettler analytical balance, and ranged from a mean of 0.4508 $\pm$ 0.0961 (S.E.$_{\bar{x}}$) grams for Symphoricarpos orbiculatus to a mean of 0.7924 $\pm$ 0.2310 grams for Rhus glabra (Table 2).

Analyses for energy content were made by igniting pelleted seed material in a Parr series 1200 adiabatic calorimeter using a Parr 1101 oxygen bomb under 30 atmospheres of oxygen. Ten centimeters of Parr "Chromel C" fuse wire were used in ignition of all samples. Parr Chrome-Nickel stainless steel capsules were used as pellet containers, an electric water heater was used to regulate the water temperature in the calorimeter jacket, and a transformer type ignition unit was used to ignite all samples. Standardizations for water equivalent and other test caloric determinations were made with benzoic acid pellets. Mercurial thermometers with ranges from 18.8 to 35.0°C. were employed for all temperature determinations. Temperature observations were made to 0.01°C. using thermometer reading lenses. Temperatures were recorded when they stabilized for at least three minutes after ignition.

Corrections for formation of acids during combustion were made by titrating the washings from the bombings with a 0.0725 normal sodium carbonate solution. Exothermic heat liberated by burning fuse wire was determined by measuring the unburned fuse wire with a ruler (2.3 cal/cm of burned wire).

Four analyses for energy content were determined for each sample, using the same equipment. Caloric data were transferred to IBM computer cards and analysis of variance techniques were used to test for differences of mean seed energy values between and within range growth sites. Punched cards were analyzed by an IBM 1410-1401 combination computer system. Other statistical processes, including t-tests and the determinations of standard errors of means and Fisher Least Significant Differences, applied to the data follow methods described by Fryer (1966).

RESULTS

Eighty caloric determinations were made for each of the nine species of seeds collected, resulting in a total of 720 determinations during the study. Results of 12 benzoic acid tests made throughout this study showed a 0.5 percent variation, reflecting the precision of the equipment and procedure. However, for seed materials, which were more variable in composition and size, a variation coefficient of not more than 2.5 percent for four determinations, was accepted as satisfactory. Table 2 presents mean energy and titration values and mean sample weights of seed materials tested.

Table 2. Mean energy values, sample weights and titration values of seeds of nine species of common plants from the Flint Hills region of northeastern Kansas.

Species	Mean Sample Weight (gms dry wt)	Acid Titration (ml/gm)	Mean Energy Value (cal/gm)
Solanum rostratum	0.7560 ± 0.1620[a]	11.19 ± 2.86[a]	6020.32 ± 7.16[b]
Rhus glabra	0.7924 ± 0.2310	8.57 ± 2.12	5205.39 ± 5.26
Ambrosia trifida	0.6510 ± 0.0986	11.42 ± 3.30	5283.15 ± 7.42
Setaria lutescens	0.6852 ± 0.1023	10.48 ± 2.28	4402.65 ± 5.67
Bromus japonicus	0.4987 ± 0.0638	8.60 ± 1.94	4353.24 ± 7.79
Helianthus annuus	0.7295 ± 0.2304	11.61 ± 2.61	5573.41 ± 6.64
Rhus aromatica	0.6727 ± 0.1211	10.47 ± 2.86	5303.88 ± 6.31
Cornus drummondi	0.6982 ± 0.1812	9.13 ± 1.91	4923.02 ± 6.41
Symphoricarpos orbiculatus	0.4508 ± 0.0961	6.75 ± 1.21	4661.65 ± 5.56

[a]Mean ± one standard error; standard errors calculated from 80 observations.

[b]Mean ± one standard error; standard errors calculated from error mean squares.

Mean energy values of <u>Solanum</u> <u>rostratum</u> seeds for the four growth sites were: Lowland, 5902.71 ± 14.30[1] cal/gm; Ordinary Upland, 6100.24 ± 14.30 cal/gm; Limestone Breaks, 6070.89 ± 14.30 cal/gm; Clay Upland, 6003.46 ± 14.30 cal/gm. All mean energy values of seeds collected at range growth sites were the result of 20 determinations; four determinations for the sample collected at each of five different areas. A pooled mean of 6020.32 ± 7.16 cal/gm was obtained for the total 80 determinations. Coefficients of variation ranged from 0.35 percent to 2.17 percent. The analysis of variance revealed no significant differences ($P > 0.05$) of mean energy values of <u>Solanum</u> <u>rostratum</u> seeds between range growth sites. However, mean energy values between areas within sites were significantly different ($P < 0.05$) (Appendix, Table 5).

Mean energy values of <u>Rhus</u> <u>glabra</u> seeds for the four range growth sites were: Lowland, 5155.02 ± 10.53 cal/gm; Ordinary Upland, 5213.93 ± 10.53 cal/gm; Limestone Breaks, 5058.32 ± 10.53 cal/gm; Clay Upland, 5394.30 ± 10.53 cal/gm. Each mean was the result of 20 determinations; four determinations having been made for the sample collected at each of five different collecting areas. A pooled mean of 5205.39 ± 5.26 cal/gm was obtained for the total 80 determinations. Coefficients of variation ranged from 0.22 percent to 1.60 percent. The analysis of variance revealed no significant differences

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[1]Mean ± standard error; all standard errors were calculated from the error mean square.

($P > 0.05$) of mean energy values of Rhus glabra seeds between range growth sites. However, mean energy values between areas within sites were significantly different ($P < 0.05$) (Appendix, Table 6).

Mean energy values of Ambrosia trifida seeds for the four range growth sites were: Lowland, 5253.05 ± 14.90 cal/gm; Ordinary Upland, 5420.14 ± 14.90 cal/gm; Limestone Breaks, 5283.89 ± 14.90 cal/gm; Clay Upland, 5175.52 ± 14.90 cal/gm. Each mean was the result of 20 determinations; four determinations having been observed for the sample collected at each of five different collecting areas for each site. A pooled mean of 5283.15 ± 7.42 cal/gm was obtained for the total 80 determinations. Coefficients of variation ranged from 0.33 percent to 2.20 percent. The analysis of variance revealed no significant differences ($P > 0.05$) of mean energy values of Ambrosia trifida seeds between range growth sites. However, differences of energy values between areas within sites were found to be highly significant ($P < 0.05$) (Appendix, Table 7).

Mean energy values of Setaria lutescens seeds for the four growth sites were: Lowland, 4344.35 ± 11.29 cal/gm; Ordinary Upland, 4345.72 ± 11.29 cal/gm; Limestone Breaks, 4447.61 ± 11.29 cal/gm; Clay Upland, 4472.93 ± 11.29 cal/gm. Each mean was the result of 20 determinations; four determinations having been observed for the sample collected at each of five different collecting areas for each site. A pooled mean of 4402.65 ± 5.67 cal/gm was obtained for the total 80 determinations.

Variation coefficients ranged from a low of 0.43 percent to 1.92 percent. The analysis of variance revealed no significant differences ($P > 0.05$) of mean energy values of <u>Setaria lutescens</u> seeds between range growth sites. However, different energy values between areas within sites were found to be highly significant ($P < 0.05$) (Appendix, Table 8).

Mean energy values of <u>Bromus japonicus</u> seeds for the four range growth sites were: Lowland, 4371.87 ± 15.58 cal/gm; Ordinary Upland, 4313.02 ± 15.58 cal/gm; Limestone Breaks, 4331.91 ± 15.58 cal/gm; Clay Upland, 4396.17 ± 15.58 cal/gm. Means for the range growth sites were the result of 20 determinations; four determinations having been observed for the sample collected at each of five different collecting areas for each site. A pooled mean of 4353.24 ± 7.79 cal/gm was obtained for the total 80 determinations. Variation coefficients ranged from a low of 0.35 percent to 3.83 percent. The analysis of variance revealed no significant differences ($P > 0.05$) of mean energy values of <u>Bromus japonicus</u> seeds between range growth sites. However, different energy values between areas within sites were found to be significant ($P < 0.05$) (Appendix, Table 9).

Mean energy values of <u>Helianthus annuus</u> seeds for the four growth sites were: Lowland, 5619.43 ± 13.26 cal/gm; Ordinary Upland, 5575.04 ± 13.26 cal/gm; Limestone Breaks, 5589.60 ± 13.26 cal/gm; Clay Upland, 5589.55 ± 13.26 cal/gm. Each was the result of 20 determinations; four determinations having

been observed for the sample collected at each of five different collecting areas for each site. A pooled mean of 5573.41 ± 6.64 cal/gm was obtained for the total 80 determinations. Variation coefficients ranged from 0.14 percent to 3.48 percent. The analysis of variance revealed no significant differences ($P > 0.05$) of mean energy values of *Helianthus annuus* seeds between range growth sites. However, different energy values between areas within sites were found to be significant ($P < 0.05$) (Appendix, Table 10).

Mean energy values of *Rhus aromatica* seeds for the four range growth sites were: Lowland, 5447.63 ± 12.64 cal/gm; Ordinary Upland, 5256.07 ± 12.64 cal/gm; Limestone Breaks, 5242.10 ± 12.64 cal/gm; Clay Upland, 5269.73 ± 12.64 cal/gm. Means for the range growth sites were the result of 20 determinations; four determinations having been observed for the sample collected at each of five different collection areas for each site. A pooled mean of 5303.88 ± 6.31 cal/gm was obtained for the total 80 determinations. Variation coefficients ranged from 0.09 percent to 1.78 percent. The analysis of variance revealed significant differences ($P < 0.05$) of mean energy values of *Rhus aromatica* seeds between range growth sites. Similarly, different energy values between areas within sites were found to be significant ($P < 0.05$) (Appendix, Table 11).

Mean energy values of *Cornus drummondi* seeds for the four range growth sites were: Lowland, 4994.55 ± 12.82 cal/gm;

Ordinary Upland, 4939.25 ± 12.82 cal/gm; Limestone Breaks, 4772.41 ± 12.82 cal/gm; Clay Upland, 4985.85 ± 12.82 cal/gm. Means for the range growth sites were the result of 20 determinations; four determinations having been observed for the sample collected at each of five different collecting areas for each site. A pooled mean of 4923.02 ± 6.41 cal/gm was obtained for the total 80 determinations. Variation coefficients ranged from 0.23 percent to 2.43 percent. The analysis of variance revealed no significant differences ($P > 0.05$) of mean energy values of Cornus drummondi seeds between range growth sites. However, different energy values between areas within sites were found to be highly significant ($P < 0.05$) (Appendix, Table 12).

Mean energy values of Symphoricarpos orbiculatus seeds for the four range growth sites were: Lowland, 4613.40 ± 11.10 cal/gm; Ordinary Upland, 4735.09 ± 11.10 cal/gm; Limestone Breaks, 4629.09 ± 11.10 cal/gm; Clay Upland, 4668.65 ± 11.10 cal/gm. Means for the range growth sites were the result of 20 determinations; four determinations having been observed for the sample collected at each of five different collection areas for each site. A pooled mean of 4661.65 ± 5.56 cal/gm was obtained for the total 80 determinations. Variation coefficients ranged from 0.19 percent to 1.64 percent. An analysis of variance revealed no significant differences ($P > 0.05$) of mean energy values of Symphoricarpos orbiculatus seeds between range growth sites. However, different energy

values between areas within sites were found to be highly significant ($P < 0.05$) (Appendix, Table 13).

Table 14 (Appendix) presents F values, degrees of freedom, regions of rejection and ultimate decisions regarding the equality of means being tested by the analysis of variance.

Fisher Least Significant Difference multiple comparison procedures were performed on significant means. No evidence was found that suggested the same collection areas produced similar increases or decreases in energy values of seeds from different species of plants.

Mean titration values, calculated on a per gram basis, were determined for all species. No observable correlation was found between energy values and mean titration values (Table 2).

An experiment to determine the atmospheric water uptake by 8.0309 grams of exposed dry seed material, showed 0.4559 and 0.5054 gram weight increases (5.66 and 6.34 percent, respectively) at 40 and 70 percent relative humidity, respectively, during a 180-minute time period (Fig. 1).

Results of an analysis of Rhus glabra seed material stored at -22°C. for nine months revealed no significant ($P \quad 0.05$) loss in energy ($t = 0.726$; d.f. = 7; region of rejection $t > 2.37$).

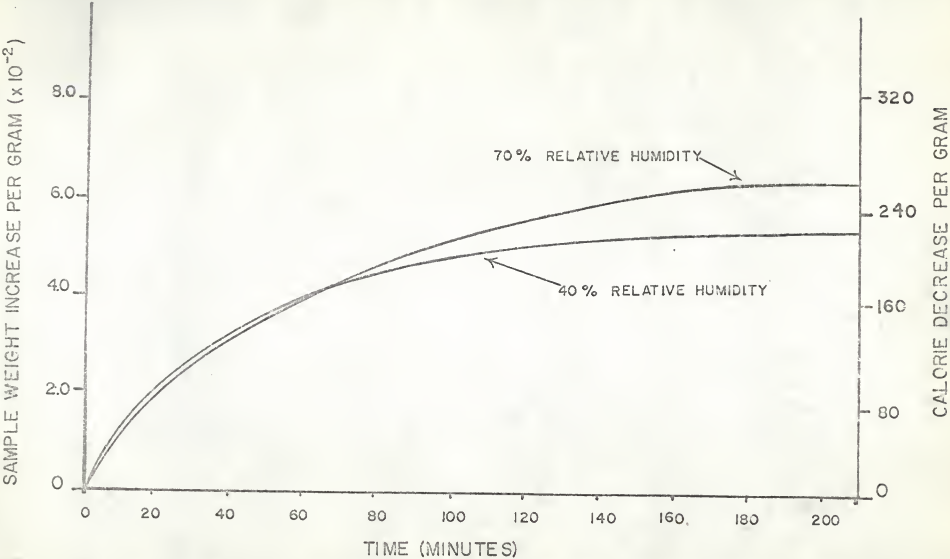

Fig. 1. Sample weight increase and corresponding caloric value decrease caused by atmospheric water absorption of 1-gram dry, ground corn (*Zea mays*).

DISCUSSION

All seeds were collected between 26 August 1966 and 7 March 1967, with the majority collected during the 1 September 1966-30 November 1966 period. It was assumed that no significant loss of energy could have occurred in seeds collected during this period of time. Robel and Harper (1965:405) found no significant changes in energy content of *Ambrosia trifida* and *Helianthus annuus* seeds during the 20 October 1964-4 February 1965 period under field conditions. Similarly, Derksen (Personal communication) detected no significant energy loss in seeds of several species under field and controlled conditions for periods extending over seven months.

Since wild granivores consume primarily solid mature seeds (Robel 1966:137), the energy dynamics of rotten or insect damaged seeds is of little importance as a basis for studies of granivore bioenergetics relationships. For this reason, damaged or otherwise abnormal, including insect infested seeds were discarded from samples. Some *Helianthus annuus* seeds were observed to be hollowed and inhabited by small insect larvae of the families Curculionidae and Incurvariidae. *Ambrosia trifida* seeds also were inhabited by Curculionidae larvae and also similar larvae from the families Torticicidae and Olethreutidae (D. V. Derksen, Personal communication).

The portions of seeds analyzed in this study were those actually consumed by bobwhite quail in Kansas. Seeds of

Helianthus annuus, Ambrosia trifida, Rhus glabra and R. aromatica and Setaria lutescens were observed to have the seed coat intact about the seed when found in the crops of bobwhites (R. J. Robel, Personal communication). Seeds of Bromus spp. were lacking glumes, lemmae and paleae in quail crops; and Cornus drummondi fruits were seldom observed in crops with the pulpy outer portion still adherent to the inner pit. Seeds of Solanum rostratum were always lacking the bristly capsule from which seeds are dispersed, when observed in crops of pheasant. Symphoricarpos orbiculatus plants produced a multitude of fruits ranging in size from 0.5- to 7.0-millimeters. The smaller fruits produced no viable seeds, therefore, all fruits which passed through a Tyler 4.70-millimeter (opening) sieve were discarded, and only those with normal appearing seeds were retained for calorimetric analysis.

Some seeds, especially those of Bromus japonicus, were difficult to collect in sufficient quantities to produce 5-grams of oven dried material. When samples less than 5-grams were collected, a larger second sample was collected and the first sample discarded.

The Parr Manual (1960) stated that the American Society for Testing Materials requires a 0.3 percent accuracy for results of calorimetric tests of the same material made in the same laboratory, and a 0.5 percent accuracy for tests made in different laboratories. The author has not achieved this degree of accuracy, and has accepted as satisfactory a variation

coefficient of not more than 2.5 percent for the results of four caloric tests made on the same sample of seed material. Similarly, Golley (1961:581) recognized as satisfactory a variation of not more than 3.0 percent for three tests of the same material. Only one value was obtained during my study that exceeded this 2.5 percent level, that being a value of 3.8 percent for a sample of *Bromus japonicus*. Benzoic acid tests revealed a variation of 0.5 percent for 12 determinations, reflecting a high degree of precision for the equipment and procedure, however, seed materials have certain properties which do not allow this degree of precision. Milling procedures did not produce homogeneously sized seed particles. Heavier particles settle to the bottom of the petri dishes and unless stirring the seed material precedes testing, it is possible to introduce error into the subsampling procedure which could account for a gain or loss of significant numbers of calories.

More oily seeds analyzed during this study were observed to yield higher energy values. Korschgen (1964) reported low fat values for *Setaria spp.* and *Symphoricarpos orbiculatus*, and higher values for *Helianthus annuus*, *Rhus glabra*, *Ambrosia trifida* and *Cornus drummondi*. Fat values compare favorably to energy values of these species (Table 3).

Bromus japonicus and *Helianthus annuus* seeds were two species with which ignition problems were encountered. With heterogeneous seed material such as *Bromus japonicus*, it is

Table 3. Comparisons of fat values reported by Korschgen (1964:164) and energy values of seeds determined in this study.

Species	Fat Value (percent of wt.)	Caloric Value (Cal/gm)
Setaria spp.	5.2	4402.65 ± 5.67
Symphoricarpos orbiculatus	5.8	4661.65 ± 5.56
Cornus drummondi	30.0	4923.02 ± 6.41
Rhus glabra	16.3	5205.39 ± 5.26
Ambrosia trifida	23.6	5283.15 ± 7.42
Helianthus annuus	26.1	5573.41 ± 6.64

believed that the finer particles ignited rapidly causing turbulence which resulted in the larger particles being blown from the confining capsule into the bottom of the bomb. A significant amount of energy is lost as a result of these "blow-outs". This problem was reduced by regrinding the seed material successively through smaller screens in the milling process, and reducing the weight of the test sample. Blow-outs of *Helianthus annuus* seed materials were eliminated by pulverizing ground seed materials in a mortar with pestle before conducting the energy analyses.

Oily seeds, such as those of *Rhus glabra*, *R. aromatica*, *Solanum rostratum*, *Cornus drummondi*, *Ambrosia trifida* and *Helianthus annuus* were ground in the micromill at a slow rate of speed (800 r.p.m.). A slow rotation of the blades in the grinder reduced the formation of an oily paste caused by

friction-induced heat in the mill. No doubt some volatile oils are lost during the grinding process of all seeds, possibly, however, this loss was minimized by milling seeds at slow speeds. Kendeigh and West (1965:553) stated that crushed seeds, as opposed to uncrushed seeds, yielded lower caloric values by a mean of 129 cal/gm. The reason for this decrease in caloric value might have been due to loss of oils during the crushing process.

It was observed that oily seed material pelleted under pressure (greater than 500 kg/cm^2) resulted in a loss of oils. For this reason, only slight pressure, sufficient to produce a firm pellet, was applied to the seed material. The appropriate pressure for seed pelleting was determined by trial and error, as was also the case for determinations of the appropriate pellet size to produce optimum combustion in the bomb.

Seed material left uncovered in a room during the testing process absorbed enough water to increase the initial sample weight by 6.30 percent. This increase in sample weight could theoretically have resulted in a decrease of 260 cal/gm if a 1-gram sample had been taken from this seed material (Fig. 1). To minimize the uptake of atmospheric water, all ground seed materials were stored at 60°C. prior to and during all analysis procedures.

Corrections were not made for ash remaining in the confining capsule after combustion. Bell (1955) stated that ash corrections were not critical in oxygen bomb calorimetry

procedures. The energy value per gram ash free dry weight (net energy) might more accurately reflect the true energy value for the purposes of some bioenergetics studies. Since ash production was low, only gross energy values were determined for all seed samples in this study. Non-oily seeds such as *Bromus japonicus*, *Setaria lutescens* and *Symphoricarpos orbiculatus* produced a slight charr (exclusive of silica) in the confining capsule after combustion. Oily seeds such as *Rhus glabra* and *R. aromatica* and *Solanum rostratum* yielded more silica ash after combustion. All seeds were relatively clean; decreasing ash production due to contamination.

Mean titration values for the nitric acid corrections did not reflect energy content of seeds. Nevertheless, a trend in titration values following mean energy values was evident (Table 2). Titration values indicate relative amounts of nitrogen present in the seed material and in the air of the bomb during combustion. Assuming a constant amount of nitrogen in the atmosphere of the bomb, a greater number of peptide and polypeptide bonds broken during combustion plus the quantity of nucleic acids present in the seeds would probably result in higher titration values. In the future, titration values may have some use in determining protein content of seeds.

The mean energy value of 5283.15 $\pm$ 7.42 cal/gm for *Ambrosia trifida* seeds obtained from this study is slightly lower than the value of 5460.3 cal/gm reported by Robel and Harper (1965:402) for seeds collected in the same region of

Kansas. Robel and Harper observed Helianthus annuus seeds to yield 5944.3 cal/gm, whereas results from this study show only 5573.41 ± 6.64 cal/gm. Robel and Harper collected seeds after the 1964 growing season, a relatively wet year with 23.86 inches of precipitation being recorded for the Manhattan, Kansas area during the April-September period (U. S. Dept. Comm., Weather Bureau, 1964). Seeds for my study were collected after the 1966 growing season in which only 12.23 inches of precipitation were recorded for the Manhattan area for the same April-September period (U. S. Dept. Comm., Weather Bureau, 1966). The amount of soil moisture present during the growing season may have influenced the quality of fruits. Even more in contrast to energy values obtained for Helianthus annuus seeds in Kansas is the value of 6759.2 cal/gm recorded for H. annuus in California by Long (1934:328). The high caloric value reported by Long might well be attributed to geographically associated environmental factors. My study has shown that significant differences in energy content of seeds are present between counties in Kansas. Differences of energy values of seeds collected at distant points on a continent may be even greater.

Derksen (Personal communication) reported a caloric value of 5862 ± 119 cal/gm for H. annuus seeds collected in the Manhattan, Kansas area in 1966, which is higher than 5573.41 ± 6.64 cal/gm obtained in my study. During 1965, however, Derksen found H. annuus seeds to yield 5550 ± 39 cal/gm.

Derksen reported a value of 5577 ± cal/gm for Ambrosia trifida seeds collected in 1966, which is also higher than 5283.15 ± 7.42 cal/gm obtained for my study. Kendeigh and West (1965:555) reported a value of 5802 cal/gm for A. trifida seeds collected in Illinois. Seeds for the study described herein were collected in 21 different areas in three counties. It is reasonable to assume that seeds collected over a large area are more representative of the true mean energy value of the species than those collected in one geographic area.

An energy value of 5282 ± 35 cal/gm for Rhus glabra and 4387 ± 96 cal/gm for Setaria lutescens was reported by Derksen (Personal communication), both of which compare favorably with 5205.37 ± 5.26 cal/gm and 4402.65 ± 5.67 cal/gm, respectively, obtained in my study for the same species. Schmid (1965) reported an energy value of 4550 cal/gm for Setaria spp. seeds collected in North Dakota.

Energy values for Bromus japonicus, Rhus aromatica, Cornus drummondi and Symphoricarpos orbiculatus have not been reported in the literature.

It has been observed from compilations of energy data (Cummins 1966; Kendeigh and West 1965; Golley 1959; Golley 1961) and from this study that in many instances plants genetically related are similar in energy content. The family gramineae in general produces seeds which yield approximately 4500 cal/gm. Polygonaceae seeds yield approximately 4600 cal/gm. Ellison (1966) reported that caloric values of needles

of black spruce (Picea mariana) and white spruce (Picea glauca) were not significantly different (5089 and 4948 cal/gm; $P > 0.01$). In my study, Rhus glabra and R. aromatica seeds yielded similar energy values of 5205.39 ± 5.26 and 5303.88 ± 6.31 cal/gm, respectively. McNair (1945) stated that oils of most of the smaller families of plants are very similar in chemical composition. Since oils and fats are primarily responsible for energy yields in seeds, this intrafamilial relationship in energy value would agree with McNair's findings. McNair (1945) found oils of larger families of plants to be quite dissimilar, tribal groups quite similar, and species within the same genus very similar. McNair also showed that the effects of soil types on oil formation varied with seasonal conditions.

Mean energy values of all species of plant seeds analyzed in this study, with the exception of Rhus aromatica were not significantly different ($P > 0.05$) between range growth sites. Range growth sites are based on degree of slope, amount and degree of erosion and soil conditions such as depth, texture, water content and water holding capacity, and general superficial soil characteristics. These factors alone might not influence the quality of seeds produced. An analysis of variance did reveal significant differences between collection areas within sites ($P < 0.05$). These results strengthen the hypothesis that geographically associated environmental factors do effect the quality of seeds. Plant-soil water relations

may be the critical factors limiting quality and quantity of seeds produced by plants. Factors such as macro- and micronutrient supplies in the soil and soil pH may also be limiting when one is concerned with the energy content of seeds produced at different geographic locations. The amount of organic matter present in different soils at different geographic locations may influence energy content of plant seeds. The amount of soil moisture plays a major role in making macro- and micronutrients and organic matter available to plants, especially during the period when seeds are being produced. Rainfall in the Flint Hills region of northeastern Kansas fluctuates greatly between years and varies greatly within small areas, making the quantity of water available to plants for seed production highly variable between years and within a geographic area during the same year. Since fat and carbohydrate production in plants is dependent upon water and carbon dioxide, variations in precipitation between geographic areas during the time of seed production may have marked effects upon the percent of carbohydrates, fats, fatty acids and protein present within seeds.

In this study all seeds collected from plants were assumed to be mature. Maturity was based primarily upon seed dispersal and secondarily upon utilization of seeds as foods by animals. The stage of maturity is a critical factor with respect to energy values. McNair (1945) stated that during ripening there is an increase in the amount of unsaturated

acids of drying oils. During the later stages of seed ripening there is a marked decrease in the oil content and seed size, however, in the final stage of maturity there is an abrupt increase in oils. All maturing seeds show an increase in the percentage of oil accompanied by a decrease in carbohydrate percentage. Seeds collected before maturity, therefore, could yield lower energy values, decreasing the experimentally determined energy value for the species and possibly indicating false differences in energy content of seeds collected in different areas.

Ideally in a study such as this, seeds of all nine species of plants studied should be collected from the same growth site in each of five different collection areas. However, in this study plants were not found to be random in their distribution and were collected where present. Much work is still needed to determine what factor or group of factors is responsible for the differences in energy values of plant seeds produced in different geographic locations. Higher energy values of seeds might reflect optimal environmental conditions for the plant. Controlled studies are needed in which different species of plants could be cultivated at different locations, and their seeds harvested and compared with the same and different species grown at other locations. Studies where accurate measurements could be obtained of environmental factors, both edaphic and climatic, are needed. Genetic variation should not be overlooked as a possible cause of energy

content variation of seeds. Clonal relations have been observed in plants since Bonnier reported his finding concerning this subject in 1920. Heslop-Harrison (1964) showed that small amounts of gene-exchange may be possible between neighboring panmictic populations, but between the extremes, the actual rate of gene exchange achieved may be so slight as to be negligible even though no actual breaks in distribution occur. Therefore, genetic divergence within a population continuum may be possible and expressed in biochemical and energetic relationships. Such genetic variants to which Heslop-Harrison is referring are more extreme than those occurring in this study, however, such genetic factors should not be overlooked as possible sources of intraspecific energy variations.

SUMMARY

Basic to comprehensive studies of the energy dynamics of organisms, it is necessary to be aware of variations in energy content of foods available to and consumed by that organism.

In the fall of 1966, a study was initiated to determine the effects of growth site location upon the energy content of seeds consumed by unconfined granivores in the Flint Hills region of northeastern Kansas. Seeds were collected from the Lowland, Ordinary Upland, Limestone Breaks, and/or Clay Upland range sites described by Anderson and Fly (1955) in 21 different locations throughout three counties. Mature seeds of <u>Solanum rostratum</u>, <u>Rhus glabra</u>, <u>Ambrosia trifida</u>, <u>Setaria</u>

lutescens, Bromus japonicus, Helianthus annuus, Rhus aromatica, Cornus drummondi and Symphoricarpos orbiculatus were collected between 26 August and 7 March 1967, with the majority of samples collected between 1 September and 30 November. Samples of the same species were collected from each of the four range growth sites in five different areas, resulting in 20 seed samples collected for each species. Seeds were sorted, dried, milled, pelleted and weighed prior to caloric determinations. Energy values for seed materials were determined with a Parr series 1200 adiabatic calorimeter using a Parr 1101 oxygen bomb under 30 atmospheres of oxygen.

Four calorimetric determinations were made for each sample collected, resulting in 80 determinations per species with a total of 720 determinations for the entire study. Caloric data were transferred to IBM computer cards and analysis of variance techniques were conducted to test for differences in mean energy values between and within range growth sites. Punched cards were analyzed by an IBM 1410-1401 combination computer system.

Seeds of Solanum rostratum, Helianthus annuus, Rhus glabra, Ambrosia trifida and Rhus aromatica had high mean energy values; 6020.32 ± 7.16, 5573.41 ± 6.64, 5202.39 ± 5.26, 5283.15 ± 7.42, and 5303.88 ± 6.31 cal/gm, respectively, while seeds of Cornus drummondi and Symphoricarpos orbiculatus had lower energy values of 4923.02 ± 6.41 and 4661.65 ± 5.56 cal/gm respectively. Lowest energy values were exhibited by grass seeds, with

4402.65 ± 5.67 and 4353.24 ± 7.79 cal/gm being the mean value of *Setaria lutescens* and *Bromus japonicus* seeds, respectively.

Mean energy values were calculated for seeds collected at each of the four range sites for each species, and also for the different areas within range growth sites. An analysis of variance revealed no significant differences ($P > 0.05$) of mean energy values between range growth sites, except for *Rhus aromatica* seeds. Mean energy values of all seeds were significantly different ($P < 0.05$) for areas within sites.

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APPENDIX

Table 4. Legal descriptions of seed collection areas in the Flint Hills region of northeastern Kansas.

Area Number	Area Description[a]	County
1	SE 1/4 - NE 1/4 - NE 1/4 Section 32, T. 11 S., R. 8 E.	Geary
2	SE 1/4 - SE 1/4 - NE 1/4 - SE 1/4 - Section 8, T. 12 S., R. 7 E. and N 1/2 - NW 1/4 - SE 1/4 - SE 1/4 - Section 8, T. 12 S., R. 7 E.	Geary
3	W 1/2 - NE 1/4 - SW 1/4 - Section 27, T. 9 S., R. 7 E.	Riley
4	NE 1/4 - SE 1/4 - Section 7, T. 10 S., R. 7 E.	Riley
5	SW 1/4 - NW 1/4 - NW 1/4 - Section 28, T. 11 S., R. 7 E.	Geary
6	SE 1/4 - NW 1/4 - NE 1/4 - Section 31, T. 10 S., R. 7 E.	Riley
7	S 1/2 - NW 1/4 - NW 1/4 - Section 33, T. 9 S., R. 7 E.	Riley
8	N 1/2 - NE 1/4 - NW 1/4 - SW 1/4 - Section 35, T. 9 S., R. 7 E.	Riley
9a.	NE 1/4 - SE 1/4 - NW 1/4 - Section 22, T. 12 S., R. 7 E.	Geary
9b.	SE 1/4 - SE 1/4 - NE 1/4 - Section 23, T. 12 S., R. 7 E.	Geary
9c.	W 1/2 - SW 1/4 - NW 1/4 - SW 1/4 - Section 24, T. 12 S., R. 7 E.	Geary
10	S 1/2 - NW 1/4 - NW 1/4 - Section 31, T. 10 S., R. 7 E.	Riley
11	SW 1/4 - N 1/2 - NW 1/4 - Section 32, T. 10 S., R. 8 E.	Riley
12	S 1/2 - SW 1/4 - NW 1/4 - Section 34, T. 11 S., R. 7 E.	Geary
13	N 1/2 - NE 1/4 - Sw 1/4 - Section 2, T. 12 S., R. 7 E.	Geary

Table 4 (concl.).

Area Number	Area Description[a]	County
14	E 1/2 - NW 1/4 - SE 1/4 - Section 36, T. 12 S., R. 7 E.	Geary
15a.	NW 1/4 - NE 1/4 - NE 1/4 - Section 1, T. 10 S., R. 6 E.	Riley
15b.	SW 1/4 - NE 1/4 - NW 1/4 - NW 1/4 - Section 1, T. 10 S., R. 6 E.	Riley
15c.	S 1/2 - SE 1/4 - SE 1/4 - Section 35, T. 9 S., R. 6 E.	Riley
16	SW 1/4 - NE 1/4 - SW 1/4 - Section 17, T. 11 S., R. 7 E.	Riley
17	N 1/2 - N 1/2 - NW 1/4 - Section 31, T. 12 S., R. 7 E.	Riley
18a.	W 1/2 - SE 1/4 - NW 1/4 - Section 33, T. 9 S., R. 8 E.	Pottawatomie
18b.	W 1/2 - SE 1/4 - SE 1/4 - Section 28, T. 12 S., R. 8 E.	Pottawatomie
19	NW 1/4 - SW 1/4 - SW 1/4 - SW 1/4 - SW 1/4 - Section 8, T. 12 S., R. 7 E.	Geary
20	S 1/2 - SW 1/4 - SW 1/4 - SW 1/4 - Section 8, T. 12 S., R. 7 E.	Geary
21	SW 1/4 - SE 1/4 - NE 1/4 - Section 19, T. 12 S., R. 8 E.	Geary

[a]Taken from United States Dept. Int. Geol. Surv. map of Manhattan, Kansas Quadrangle (1947).

Table 5. Mean energy values of _Solanum rostratum_ seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	1	6085.99 ± 39.79				
	9a.	6188.31 ± 67.23				
	20	5820.04 ± 41.74				
	2	5542.86 ± 18.50				
	5	5896.34 ± 16.60	20	5906.71 ± 14.30		
Ordinary Upland	10	5984.12 ± 18.95				
	6	6080.10 ± 10.80				
	18	6094.50 ± 36.12				
	2	6112.10 ± 13.10				
	21	6230.51 ± 14.66	20	6100.24 ± 14.30		
Limestone Breaks	18	6063.94 ± 17.15				
	11	5942.77 ± 29.88				
	9c.	6003.44 ± 27.76				
	15b.	6212.82 ± 44.58				
	17	6131.51 ± 31.13	20	6070.89 ± 14.30		
Clay Upland	10	6038.85 ± 21.33				
	18	6060.70 ± 23.21				
	14	5685.29 ± 29.46				
	7	6106.90 ± 47.68				
	9a.	6125.54 ± 31.42	20	6003.46 ± 14.30	80	6020.32 ± 7.16

[a] See Table 4 for locations of collection areas.

[b] Means ± one standard error; each standard error calculated from four determinations.

[c] Means ± one standard error; each standard error calculated from error mean square.

Table 6. Mean energy values of *Rhus glabra* seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	10	5447.19 ± 21.05				
	8	5238.84 ± 7.41				
	6	4910.91 ± 34.21				
	9a.	5344.65 ± 42.74				
	5	4833.50 ± 33.27	20	5155.02 ± 10.53		
Ordinary Upland	6	5279.59 ± 22.02				
	1	4961.64 ± 39.75				
	5	5176.60 ± 21.67				
	8	5231.76 ± 31.39				
	4	5420.09 ± 5.84	20	5213.93 ± 10.53		
Limestone Breaks	5	4846.60 ± 7.62				
	11	4701.18 ± 9.87				
	9a.	5212.21 ± 16.48				
	2	5099.69 ± 17.44				
	10	5410.81 ± 11.21	20	5058.32 ± 10.53		
Clay Upland	10	5365.72 ± 34.84				
	8	5457.68 ± 23.20				
	5	5315.40 ± 5.98				
	12	5404.14 ± 12.97				
	4	5428.54 ± 15.51	20	5394.30 ± 10.53	80	5205.39 ± 5.26

[a]See Table 4 for locations of collection areas.

[b]Means ± one standard error; each standard error calculated from four determinations.

[c]Means ± one standard error; each standard error calculated from error mean square.

Table 7. Mean energy values of <u>Ambrosia trifida</u> seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	2	5230.06 ± 54.77				
	6	5457.32 ± 42.57				
	15a.	5018.76 ± 55.30				
	4	5267.40 ± 24.47				
	10	5291.74 ± 29.28	20	5253.05 ± 14.90		
Ordinary Upland	2	5259.49 ± 34.86				
	6	5364.87 ± 14.97				
	15a.	5238.43 ± 39.82				
	15c.	5831.08 ± 28.46				
	16	5406.82 ± 8.80	20	5420.14 ± 14.90		
Limestone Breaks	16	5146.47 ± 25.14				
	11	5357.43 ± 45.28				
	15a.	5096.45 ± 24.46				
	15b.	5378.53 ± 21.52				
	17	5440.56 ± 9.61	20	5283.89 ± 14.90		
Clay Upland	14	5217.59 ± 53.21				
	9c.	5143.54 ± 18.16				
	15a.	5237.12 ± 39.15				
	6	5054.91 ± 19.32				
	4	5224.44 ± 11.61	20	5175.52 ± 14.90	80	5283.15 ± 7.42

[a]See Table 4 for locations of collection areas.

[b]Means ± one standard error; each standard error calculated from four determinations.

[c]Means ± one standard error; each standard error calculated from error mean square.

Table 8. Mean energy values of *Setaria lutescens* seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	8	4404.80 ± 26.16				
	9b.	4490.29 ± 30.85				
	7	4065.37 ± 22.46				
	10	4413.73 ± 36.60				
	6	4347.58 ± 15.74	20	4344.45 ± 11.29		
Ordinary Upland	6	4336.15 ± 19.59				
	8	4296.64 ± 24.62				
	4	4298.71 ± 24.55				
	10	4266.96 ± 27.85				
	11	4530.15 ± 9.69	20	4345.72 ± 11.29		
Limestone Breaks	17	4453.13 ± 12.48				
	15a.	4253.41 ± 12.29				
	15b.	4652.95 ± 11.05				
	12	4379.37 ± 25.20				
	10	4499.18 ± 27.36	20	4447.61 ± 11.29		
Clay Upland	9c.	4515.25 ± 41.16				
	4	4441.18 ± 26.29				
	15a.	4448.03 ± 14.52				
	3	4517.23 ± 23.15				
	10	4442.94 ± 42.71	20	4472.93 ± 11.29	80	4402.65 ± 5.67

[a]See Table 4 for locations of collection areas.

[b]Means ± one standard error; each standard error calculated from four determinations.

[c]Means ± one standard error; each standard error calculated from error mean square.

Table 9. Mean energy values of <u>Bromus japonicus</u> seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	3	4329.37 ± 23.10				
	9c.	4373.56 ± 43.12				
	5	4271.94 ± 7.53				
	1	4379.66 ± 50.44				
	2	4504.80 ± 19.81	20	4371.87 ± 15.58		
Ordinary Upland	4	4244.24 ± 81.21				
	8	4383.52 ± 11.30				
	2	4329.29 ± 11.41				
	3	4319.61 ± 19.00				
	1	4288.45 ± 32.22	20	4313.02 ± 15.58		
Limestone Breaks	1	4386.91 ± 37.12				
	3	4390.89 ± 29.72				
	14	4275.13 ± 15.73				
	2	4360.59 ± 44.88				
	8	4246.06 ± 20.33	20	4331.91 ± 15.58		
Clay Upland	3	4379.81 ± 56.92				
	1	4387.11 ± 8.75				
	9c.	4391.66 ± 29.04				
	14	4361.94 ± 27.11				
	2	4460.33 ± 30.43	20	4396.17 ± 15.58	80	4353.24 ± 7.79

[a]See Table 4 for locations of collection areas.

[b]Means ± one standard error; each standard error calculated from four determinations.

[c]Means ± one standard error; each standard error calculated from error mean square.

Table 10. Mean energy values of <u>Helianthus annuus</u> seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	6	5741.09 ± 7.12				
	9b.	5777.64 ± 18.79				
	10	5424.93 ± 23.16				
	2	5634.63 ± 8.56				
	4	5518.89 ± 15.78	20	5619.43 ± 13.26		
Ordinary Upland	10	5712.83 ± 36.92				
	2	5616.95 ± 14.83				
	8	5291.07 ± 35.67				
	6	5563.71 ± 8.16				
	4	5690.63 ± 44.92	20	5575.04 ± 13.26		
Limestone Breaks	15b.	5666.89 ± 18.39				
	3	5678.21 ± 21.64				
	15a.	5613.86 ± 3.97				
	10	5445.49 ± 11.72				
	4	5543.58 ± 68.11	20	5589.60 ± 13.26		
Clay Upland	8	5490.50 ± 68.20				
	4	5733.92 ± 16.60				
	15a.	5622.24 ± 14.86				
	14	5658.75 ± 21.50				
	9c.	5442.32 ± 18.61	20	5589.55 ± 13.26	80	5573.41 ± 6.64

[a]See Table 4 for locations of collection areas.

[b]Means ± one standard error; each standard error calculated from four determinations.

[c]Means ± one standard error; each standard error calculated from error mean square.

Table 11. Mean energy values of *Rhus aromatica* seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	9c.	5353.17 ± 6.65				
	8	5431.74 ± 22.80				
	2	5465.17 ± 7.85				
	10	5433.26 ± 25.69				
	18a.	5554.82 ± 25.41	20	5447.63 ± 12.64		
Ordinary Upland	9a.	5033.44 ± 41.10				
	13	5215.02 ± 21.19				
	18a.	5292.90 ± 22.73				
	16	5234.80 ± 30.88				
	21	5449.01 ± 17.32	20	5256.07 ± 12.64		
Limestone Breaks	13	5402.64 ± 44.86				
	4	5117.73 ± 12.04				
	9c.	5354.44 ± 27.06				
	11	5234.80 ± 30.88				
	14	5100.87 ± 31.10	20	5242.10 ± 12.64		
Clay Upland	11	5112.08 ± 2.23				
	14	5285.16 ± 40.89				
	18b.	5253.20 ± 32.56				
	16	5316.89 ± 47.21				
	15a.	5381.31 ± 12.81	20	5269.73 ± 12.64	80	5303.88 ± 6.31

[a] See Table 4 for locations of collection areas.

[b] Means ± one standard error; each standard error calculated from four determinations.

[c] Means ± one standard error; each standard error calculated from error mean square.

Table 12. Mean energy values of <u>Cornus drummondi</u> seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	8	5153.74 ± 33.32				
	1	5079.43 ± 19.41				
	7	4831.53 ± 22.77				
	2	4836.96 ± 31.49				
	9a.	5071.09 ± 5.85	20	4994.55 ± 12.82		
Ordinary Upland	13	4856.66 ± 26.24				
	10	4994.77 ± 30.84				
	4	4589.31 ± 14.40				
	8	5130.67 ± 29.55				
	6	5124.83 ± 16.66	20	4939.25 ± 12.82		
Limestone Breaks	11	4853.20 ± 49.57				
	10	4806.37 ± 17.88				
	7	4241.24 ± 32.94				
	4	4947.20 ± 23.88				
	8	5014.10 ± 61.02	20	4772.42 ± 12.82		
Clay Upland	8	4965.67 ± 14.73				
	4	5056.91 ± 13.42				
	10	5033.53 ± 33.69				
	15a.	4980.24 ± 28.23				
	13	4892.91 ± 6.26	20	4985.85 ± 12.82	80	4923.02 ± 6.41

[a]See Table 4 for locations of collection areas.

[b]Means ± one standard error; each standard error calculated from four determinations.

[c]Means ± one standard error; each standard error calculated from error mean squares.

Table 13. Mean energy values of _Symphoricarpos orbiculatus_ seeds collected from four growth sites at 20 areas.

Growth Site	Collection Area Number[a]	Mean Energy Value Within Area[b] (cal/gm)	N	Mean Energy Value Within Site[c] (cal/gm)	N	Pooled Mean Energy Value[c] (cal/gm)
Lowland	16	4791.68 ± 27.20				
	2	4435.59 ± 35.68				
	9a.	4673.94 ± 28.26				
	7	4554.74 ± 23.38				
	4	4611.04 ± 16.93	20	4613.40 ± 11.10		
Ordinary Upland	8	4665.21 ± 23.94				
	9a.	4590.44 ± 35.77				
	4	4857.21 ± 20.32				
	2	4763.57 ± 32.28				
	13	4799.05 ± 23.71	20	4735.09 ± 11.10		
Limestone Breaks	7	4653.61 ± 15.33				
	4	4593.46 ± 21.59				
	9a.	4667.80 ± 4.42				
	8	4615.12 ± 12.74				
	13	4618.21 ± 34.58	20	4629.64 ± 11.10		
Clay Upland	7	4535.97 ± 15.14				
	13	4662.30 ± 27.78				
	11	4616.38 ± 27.91				
	9a.	4679.50 ± 7.84				
	16	4847.30 ± 32.01	20	4668.65 ± 11.10	80	4661.65 ± 5.56

[a] See Table 4 for locations of collection areas.

[b] Means ± one standard error; each standard error calculated from four determinations.

[c] Means ± one standard error; each standard error calculated from error mean squares.

Table 14. Results of an analysis of variance conducted on mean energy values of seeds of nine species of common plants in the Flint Hills region of northeastern Kansas.

Species	F Values For Between Site Means	Decision	F Values For Area Within Site Means	Decision
Solanum rostratum	1.29	Accept H_o [a]	27.90	Reject H_o [b]
Rhus glabra	2.19	Accept H_o	82.37	Reject H_o
Ambrosia trifida	1.87	Accept H_o	25.22	Reject H_o
Setaria lutescens	1.47	Accept H_o	23.93	Reject H_o
Bromus japonicus	1.79	Accept H_o	3.28	Reject H_o
Helianthus annuus	0.09	Accept H_o	21.17	Reject H_o
Rhus aromatica	3.30	Reject H_o	17.72	Reject H_o
Cornus drummondi	1.24	Accept H_o	52.36	Reject H_o
Symphoricarpos orbiculatus	1.37	Accept H_o	17.39	Reject H_o

[a] H_o [(all means are equal) (homogeniety of variance)] vs. H_a [(some means are unequal) (homogeniety of variance)], region of rejection = $F_{.05}(3, 16) > 3.24$.

[b] Region of rejection = $F_{.05}(16, 60) > 1.82$.

INFLUENCES OF SITE LOCATION UPON ENERGY CONTENT OF SEEDS OF SOME COMMON PLANTS OF NORTHEASTERN KANSAS

by

STEVE ROBERT JOHNSON

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AN ABSTRACT OF A MASTER'S THESIS

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A study of avian bioenergetics has been in progress at Kansas State University, Manhattan, since November 1961. When bioenergetics studies on unconfined granivores are conducted, differences in energy content of consumed seeds may be of major importance. In the fall of 1966, a study was initiated to determine the effects of growth site upon the energy content of seeds consumed by bobwhite quail (*Colinus virginianus*) in the Flint Hills region of northeastern Kansas.

Mature seeds of giant ragweed (*Ambrosia trifida*), common sunflower (*Helianthus annuus*), buffalobur nightshade (*Solanum rostratum*), smooth sumac (*Rhus glabra*) and aromatic sumac (*R. aromatica*), roughleaf dogwood (*Cornus drummondi*), buckbrush (*Symphoricarpos orbiculatus*), Japanese brome (*Bromus japonicus*) and yellow bristlegrass (*Setaria lutescens*) were collected from 26 August 1966, through 7 March 1967, with the majority collected between 1 September and 30 November 1966. Seeds were hand collected from plants growing on Lowland, Ordinary Upland, Limestone Breaks and Clay Upland range growth sites described by Anderson and Fly (1955), at 21 different locations throughout Riley, Geary and Pottawatomie counties, Kansas.

Analyses for energy content were made by igniting ground, dried, pelleted seed material in a Parr series 1200 adiabatic calorimeter using a Parr 1101 oxygen bomb under 30 atmospheres of oxygen. Parts of seeds analyzed were those actually consumed by bobwhites. Four analyses were made on each sample collected from the four range growth sites at five different

areas. Hence, 20 determinations were made per growth site, and 80 per species, resulting in a total of 720 caloric determinations for the entire study.

Seeds of Solanum rostratum, Helianthus annuus, Rhus glabra and R. aromatica and Ambrosia trifida yielded the highest energy values of 6020.32 ± 7.16 cal/gm, 5573.41 ± 6.64 cal/gm, 5205.39 ± 5.26 cal/gm, 5303.88 ± 6.31 cal/gm, and 5283.15 ± 7.42 cal/gm, respectively. Seeds of Cornus drummondi and Symphoricarpos orbiculatus yielded lower energy values of 4923.02 ± 6.41 cal/gm and 4661.65 ± 5.56 cal/gm, respectively. Grass seeds yielded the lowest energy values of 4402.65 ± 5.67 cal/gm and 4353.24 ± 7.79 cal/gm for Setaria lutescens and Bromus japonicus, respectively.

Mean energy values were calculated for seeds collected at range growth sites and areas within the sites, and an analysis of variance was applied to these data. Mean energy values for all species of seeds except Rhus aromatica were found to be nonsignificantly different between range growth sites ($P > 0.05$). However, mean energy values for all species were found to be significantly different between different collection areas within sites ($P < 0.05$). Fisher LSD multiple comparison procedures on significantly different means revealed no evidence that the same collection areas produced similar increases or decreases in energy values of seeds from different species of plants.

Experiments to determine the atmospheric water absorption

by ground, dried seed material exposed at 40 and 70 percent relative humidity, showed 5.6 and 6.3 percent increased in weight respectively, which corresponded to a 230 and 260 cal/gm energy decrease, respectively.

Monthly analyses of _Rhus glabra_ seed material stored at $-22^{\circ}C$. for nine months revealed no significant decrease in energy ($P > 0.05$).

Most oily seeds analyzed during this study were observed to yield high energy values. Korschgen (1966) reported fat values (percent of weight) for some seeds; these fat values compare favorably to energy values of the same species analyzed in my study.

Organic matter content in soil, macro- and micronutrient supply in the soil, soil-plant water relations, precipitation, stage of plant maturity, and genetic characteristics are believed to be factors which might have influenced the energy content of plant seeds in this study.